news SCAN

APPLIED PHYSICS

The Next Generation

NEW SUPERCONDUCTING WIRES COME CLOSER TO MARKET

BY GRAHAM P. COLLINS

The 1987 discovery of materials that conduct electricity perfectly at temperatures above the boiling point of nitrogen (–196 degrees Celsius) seemed to herald a revolutionary era of technology. But turning the promise of these so-called high-temperature superconductors into commercial reality has proved to be a long, arduous task. It is one thing to produce a small sample of a superconductor for experiments in a laboratory and quite another to manufacture hundreds of meters of high-quality wire for applications. Until recently, the leading commercial high-temperature superconductor technology involved wires made of the elements bismuth, strontium, calcium, copper and oxygen (BSCCO). Now a second generation of wires, composed of yttrium, barium, copper and oxygen (YBCO), looks set to dominate the marketplace.

BSCCO wires are typically made by putting a powder inside a tube of silver that is then heated and drawn out. But that technique has two significant downsides. First, the cost of the silver makes the wires expensive. Second, manufacturers have little ability to control the detailed structure of the BSCCO cores to optimize the superconductor's performance.

YBCO had other problems that early on left BSCCO in the driver's seat. The chief approach to YBCO wire making is deposition of the material onto a substrate to form a thin ribbon. YBCO, however, tends to form innumerable tiny crystal grains, and if these are not closely aligned, resistance builds up because of the jumps a current has to take from grain to grain. Yet interest in YBCO remained high because well-aligned samples stay superconducting in stronger magnetic fields than BSCCO can withstand; many applications, such as magnets and motors, require that the wires function in such fields.

Over the past decade, researchers have largely solved the crystal grain problem by depositing a layer of a material such as cerium oxide on the substrate before laying down the YBCO. The cerium oxide serves to help align the YBCO grains. Researchers, primarily at Los Alamos National Laboratory and Oak Ridge National Laboratory, have developed two wire-making technologies incorporating the grain-aligning layer. The approaches, which go by the acronyms IBAD (which uses ion beams to help align the crystals) and RABiTS (which relies on rollers and heat to prepare the substrate), have been taken up by wire-producing companies.

Much remains, however, to further improve the wires' performance. For example, although YBCO's resilience to magnetic fields exceeds that of BSCCO, even greater performance is needed for higher-field applications. In 2004 Stephen Foltyn's group at Los Alamos showed that introducing nanoparticles of barium zirconate greatly improved YBCO's magnetic characteristics. Amit Goyal and his colleagues at Oak Ridge reported similar work earlier this year.

POWER CABLE made of superconducting wire (*silvery ribbons*) is being used in a high-voltage demonstration project in Albany, N.Y.

SUMITOMO ELECTRIC INDUSTRIES

The promise of second-generation wires is so great that wire-producing companies such as American Superconductor and SuperPower have switched to producing YBCO tape in place of the older BSCCO wires. Both companies expect to deliver around 10 kilometers to customers in the coming year. By the end of 2006 SuperPower aims to have the manufacturing capacity to produce a million meters of the wire annually.

The wire comes in pieces each 100 to 300 meters long, but the companies are working on increasing that length and proudly announce when they achieve a new world-record combination of YBCO wire length and current-carrying capacity. SuperPower is now routinely producing lengths greater than 300 meters and holds the record for YBCO with a 322-meter wire.

Customers are developing devices using the second-generation wire for a variety of applications, including motors, generators, cables and transformers. The first major demonstration project involving YBCO wire will be a high-voltage cable running between two power substations in Albany, N.Y. Most of the 350-meter cable is made of BSCCO wire, but a 30-meter segment will be replaced with YBCO cable. Building that 30-meter length of cable will use up around 10 kilometers of YBCO tape. Installation and commissioning of the second-generation wire are scheduled for June 2007.

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A SUPERCONDUCTING SANDWICH

Superconducting wires made of YBCO come in the form of thin ribbons with the crucial YBCO layer no more than about 1.5 microns thick. If more YBCO is added, the current-carrying capacity of the tape does not increase significantly.

In 2004 Stephen Foltyn and his colleagues at Los Alamos National Laboratory demonstrated a wire made with layers of cerium oxide (which helps to align the YBCO crystals) interleaved with six 0.6-micron layers of YBCO. The multilayered sandwich carried currents up to 1,400 amperes per centimeter width, a YBCO record that still stands.